TASK 37 – ASH DEPOSITION COURSE

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TABLE OF CONTENTS

LIST OF FIGURES	i
LIST OF TABLES	i
ABSTRACT	ii
EXECUTIVE SUMMARY	ii
INTRODUCTION	1
SHORT COURSE CONTENTS	1
1. Introduction	2
2. Inorganic Composition of Coal and Ash	2
3. Partitioning of Inorganic Components During Combustion	2
4. Mechanisms of Ash Transport	2
5. Deposit Adhesion/Growth/Strength Mechanisms	3
6. Prediction Methods	3
7. Impact of Fuel on Boiler Design and Operation	3
8. Summary	3
9. Solving Ash-Related Problems	3
RESULTS AND DISCUSSION	4
Course Upgrading	4
Courses Presented	4
Course Evaluations	5
Future Plans	6
CONCLUSION	6

LIST OF FIGURES

1 Course ranking by participants.	6
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LIST OF TABLES

1 Completed Short Courses	5
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ABSTRACT

The goals of this Energy & Environmental Research Center project are to develop a short course for transferring technical information from the research community to the industrial community, to seek out the research needs of industry, and to continually upgrade course materials. The Coal Ash Behavior and Deposition short course developed in the project provides an overview of recent research that is increasing the understanding of mineral behavior in coal utilization. This research leads to the advancement of methods to predict ash behavior, which can economically resolve fouling problems for the utility industry.

EXECUTIVE SUMMARY

The goal of the Recent Advances in Research on Ash Deposition in Utility Boilers: Practical Applications for the Electric Power and Coal Industries project is to transfer technical information concerning ash formation and deposition in utility boilers using short course presentations. To improve the communication between researchers and the utility community, Energy & Environmental Research Center (EERC) personnel have presented 1- or 2-day short courses throughout the United States and internationally. In addition to the presentations, course materials have been continually upgraded with new research information as it becomes available.

The Coal Ash Behavior and Deposition short course provides an overview of recent research that is increasing the understanding of mineral behavior in coal utilization. This research leads to the advancement of methods to predict ash behavior, which can economically resolve fouling problems for the utility industry. Many EERC experts contributing their knowledge to specific sections of the presentation provided input to the course materials. The course materials begin with a description of minerals in coals and then discuss the physical and chemical properties of the materials as they move through the boiler. Emphasis is placed on how these properties affect boiler operation and performance. Discussions are centered on problem-solving techniques and mitigation solutions.

Eleven short courses were held at nine locations throughout the United States during the term of the project. Total course participants numbered 154 and included combustion engineers, boiler operators, fuel specialists, management, other coal researchers, and government personnel. Solicited comments and written evaluations about the content and usefulness of the course by participants were commendatory.

This project has met its goals of developing a short course for transferring technical information from the research community to the industrial community, to seek out the research needs of industry, and to continually upgrade course materials.

TASK 37 – ASH DEPOSITION COURSE

INTRODUCTION

The availability of reliable low-cost electricity is in many ways related to the inert materials contained in coals that are liberated as ash upon combustion. Ash-related problems encountered in combustion systems include the formation of fine particulates that are difficult to collect, sulfur oxide emissions, corrosion and erosion of boiler parts, and ash deposition. The economic impact of these problems is staggering. The Energy & Environmental Research Center (EERC), power generation industry, control technology vendors, and other research organizations have conducted much research in these areas. The vast amount of information produced is not always disseminated to those who actually apply the technology in an industrial setting.

The goal of this project is to transfer technical information concerning ash formation and deposition in utility boilers using short course presentations. To improve communication between researchers and the utility community, this project has presented 1- or 2-day short courses throughout the United States and internationally. In addition to the presentations, course materials have been continually upgraded with new research information as it becomes available.

The Coal Ash Behavior and Deposition short course provides an overview of recent research that is increasing the understanding of mineral behavior in coal utilization. This research leads to the advancement of methods to predict ash behavior, which can economically resolve fouling problems for the utility industry. The course materials begin with a description of minerals in coals and then discusses the physical and chemical properties of the materials as they move through the boiler. Emphasis is placed on how these properties affect boiler operation and performance. Discussions are centered on problem-solving techniques and mitigation solutions.

SHORT COURSE CONTENTS

The Coal Ash Behavior and Deposition short course is a product of the education and training mission of the EERC. Certain education and training activities are formalized in conferences, short courses, and workshops, the goal of which is to provide an avenue for communication of information and ideas among research entities, industry, government, academia, and society. Originally conceived in 1989, the short course was developed over several years. Input to the course materials was provided by many EERC experts contributing their knowledge to specific sections of the presentation. As new information becomes available, it is incorporated into the short course. The course has been variously offered as 1- to 2-day sessions, as a workshop involving specific plants, and as a 5-day in-depth training course on ash formation/deposition fundamentals and boiler operation.

Course content is normally somewhat expanded and tailored to meet the objectives of participants on the basis of their background and needs. Usually, additional literature research and materials preparation is performed to address specific utility plant problems and fuel resources. Presentation methods can include lectures and interactive discussion on course topics, computer

software demonstrations, a hands-on data analysis workshop, and problem-solving discussions related to specific power plants. The presenters are EERC personnel, generally one or two materials science researchers and a combustion engineer. Educational materials given to the participants include paper copies of the visual presentation materials and a series of relevant research papers supporting and enhancing the course topics.

The short course is constructed to follow the processes influencing ash formation and deposition from initial combustion to final deposition. The course begins with identifying the origin, composition, distribution, and association of the inorganic constituents in coal. Methods of determining the inorganic material and its associations are discussed. As ash is formed and moves through the boiler, partitioning and transport mechanisms become important. The course presents the latest information on these processes. Particle stickiness, deposit adhesion and growth, and strength development are examined in order to provide insight to fouling problems in individual boilers. Methods of predicting ash behavior and deposition are presented as tools for the evaluation of fuels and deposition problems. Current solutions to ash deposition in boilers are suggested and discussed with the attendees. The basic outline of the course follows.

1. Introduction

The introduction sets a general framework for understanding the processes, mechanisms, and transformations that occur as coal minerals pass through a combustion system. The relationship between understanding these processes and making informed operational decisions is stressed.

2. Inorganic Composition of Coal and Ash

This section discusses the inorganic constituents contained in the coal organic matrix. The particular forms and distribution of these inorganic materials are examined. Standard and advanced methods of characterization are explained and evaluated. Characteristics of U.S. coals, including eastern bituminous and western subbituminous coals and lignites, are discussed.

3. Partitioning of Inorganic Components During Combustion

Inorganic component partitioning, mineral transformations, and fly ash size evolution play a role in the propensity for fouling and slagging problems. These factors are illuminated with examples taken from research conducted at the EERC and related to full-scale systems. The relationship between original coal inorganic material coupled with combustion conditions and final ash and vapor characteristics is demonstrated.

4. Mechanisms of Ash Transport

The various mechanisms of ash transport to a deposition surface are discussed. Subjects included inertial impaction, vapor-phase and small-particle diffusion, and eddy impaction. The relationship between transport mechanisms and deposit structure is shown. Mechanisms specific to the participant's operations are discussed.

5. Deposit Adhesion/Growth/Strength Mechanisms

Ash deposition mechanisms are related to the viscosity of individual ash particles and to the physical and chemical environment around the particle. These relationships are discussed with an emphasis on identifying the specific mechanisms that cause problems in specific boiler locations. Liquid-phase formation, viscous flow sintering, and small-particle sulfation are covered.

6. Prediction Methods

Methods to predict or determine ash deposition include combustion testing, indices based on coal characteristics or advanced analytical techniques, and various stochastic and equilibrium models. The various methods are discussed with examples given from work done by the EERC and related to full-scale systems. Specific software usually discussed includes PCQUEST, an advanced fouling and slagging index model, and two mechanistic models, Fuel Quality Advisor and the ash transformation ATRAN/TraceTran pair. Emphasis is placed on using these tools to economically assess problems or potential problems in individual situations. Depending on interest, the presentation may include live software demonstrations on a laptop computer using an overhead projection panel. The PCQUEST software is relevant to many situations and is discussed at length as a tool for problem solving.

7. Impact of Fuel on Boiler Design and Operation

Subjects covered in this section include the effects of coal rank and type on boiler sizing and some important factors to consider in the convective pass region. Basic boiler operation and the relationships between boiler control parameters are discussed. Operation topics include pulverizers, sootblowers, and steam temperature control.

8. Summary

This section presents a thorough summary of the course. The goal is to reiterate the principles learned previously and assure a solid foundation for discussions in the following section. The concept of ash viscosity and sintering related to ash chemistry, size, and system operational parameters is emphasized again. In a 2-day course, this summary usually introduces the second day and serves as refresher material.

9. Solving Ash-Related Problems

This section provides an array of practical solutions to ash-fouling problems in combustion systems. Solutions are based on experimental research and full-scale system examinations. Consideration is given to fuel screening and upgrades, monitoring boiler performance, additives, and boiler modifications. Procedures to evaluate a given coal of interest for fouling and slagging propensity are discussed. Extensive discussions of specific system problems are forthcoming if the participants so desire.

RESULTS AND DISCUSSION

Course Upgrading

The original short course was a collection of slides gleaned from existing presentations plus new ones to provide continuity and additional information. A notebook containing paper copies of the slides was given to the course participants. Unfortunately, some of the graphic components did not reproduce well either as a slide or as a paper copy. Difficulty was encountered maintaining presentation flow when some of the slides contained extraneous material. The course was given in this manner several times and the reviews were good for the information and discussion presented.

This project permitted the upgrading and reorganization of the short course. New graphics were constructed where needed, and the entire course was given a consistent and professional look. All of the slides were either translated to or newly constructed on a computer. This method eased the incorporation of new data and ideas into the presentation. The notebook of paper copies improved accordingly and was constructed with the idea that it would become a reference book for the course participants.

The section on computer modeling was expanded. The EERC has done extensive research on modeling ash formation and deposition mechanisms with the goal of predicting ash behavior in combustion systems. The various models are presented in the course in order to provide tools for the operators and engineers. The models range from empirical to theoretical, and examples are given for each.

The problem-solving aspect of the short course was broadened. One of the major focus areas in the short course is the transfer of knowledge to the combustion industry with the purpose of improving the economics of their operation. Understanding ash formation and deposition behavior will lead combustion engineers, boiler operators, and management to make better-informed decisions concerning processes and system planning. This section of the short course was expanded and reorganized to include more discussion of specific industry problems. An informal survey is conducted at the start of each course to guide discussions as the course progresses. When the course is given to an individual company, the discussions are centered on problems occurring at their power plant. Emphasis throughout the course materials and presentations is placed on problem solving and providing tools for industry. Since the discussion portion of the short course has proven to be very successful and desirable to industry personnel, the course generally is presented over 1½ to 2 days. This time frame allows sufficient time for discussion and exchange of information.

Courses Presented

In order to transfer recent research knowledge to industry in a wide-ranging and timely fashion, the courses were held at various locations in the United States throughout the term of the project. Eleven courses were presented at nine locations (Table 1). Total course participants over the life of the project numbered 154. Although this number may seem low, the audience consisted

of those who benefit the most from the information and work in positions that involve making decisions that affect power plant operation and economies.

TABLE 1

Completed Short Courses			
Date	Location	Length	Attendance
February 17, 1995	Orlando, FL	1 day	12
April 21, 1995	Chicago, IL	1 day	16
October 12, 1995	Minneapolis, MN	1 day	11
May 2–3, 1996	Grand Forks, ND	1½ days	8
July 17–18, 1996	Bismarck, ND	1½ days	6
January 22, 1997	Madison, WI	1 day	20
January 27–31, 1997	Pittsburgh, PA	5 days	7
April 1–2, 1997	Estevan, SK	2 days	30
June 25–29, 1997	Grand Forks, ND	1½ days	8
September 18, 1997	Grand Forks, ND	1 day	6
January 13–14, 1998	Farmington, NM	2 days	30

The number of participants at any given course was unpredictable. Attendance figures were higher at locations either targeted to a specific industry problem or when attached to a national conference. It appears that the ability of a participant to attend the course is mostly related to travel costs.

Course Evaluations

At the completion of each short course, comments were solicited in order to evaluate the presentation. Later in the project, an evaluation sheet was distributed to participants. The participants were asked to rate each section of the course, the visual and printed course materials, and give an overall rating. Since the institution of the evaluation sheet, the course has earned an overall 4.1 out of 5 rating. These data represent responses from 42 out of 94 participants, for a response rate of 44.7%. The overall rating results are given in Figure 1. Comments received were very favorable and usually included statements relating to an increased understanding of ash formation and deposition. Other comments included suggestions to be more site-specific, use more examples, and provide more reference material. Admonitions to be less fundamental and more practical were balanced by those who wanted more technical information on the chemical and physical properties of coal-derived materials. Verbal comments about course content from individuals naturally were aligned with the person's work area and interests.

Based on participant evaluations and comments and postmeeting discussions by the instructors, course materials were modified and improved in the appropriate areas as much as practical. This was done after each course was given. Consequently, over the life of the project, the course has undergone significant improvements in both content and materials.

Figure 1. Course ranking by participants.

Future Plans

The EERC plans to continue to present the Coal Ash Behavior and Deposition short course. It is one of the best ways to facilitate the transfer of knowledge from researchers to industry personnel. It also is a mechanism for the EERC to receive feedback on research needs and ideas from industry. The course will remain as a 1- to 2-day presentation. Continual improvement in content will remain a goal. Presentation methods will improve with the conversion of the existing 35-mm slides into all-electronic media. The use of a computer video projector will ease course content upgrading and improve slide production.

CONCLUSION

The Coal Ash Behavior and Deposition short course provides participants with an extensive array of ash formation, fouling, and slagging knowledge on lignite, subbituminous, and bituminous coals only attainable through years of research. This knowledgebase gives them a foundation to solve their own power plant problems. Participants can expect to gain a better understanding of inorganic constituents in coal, ash formation mechanisms, types of ash deposition, and deposit growth and strength development. This enhanced understanding will allow better decision making relating to fuel selection, locating and identifying deposit problems, and decreasing the costs of research programs by starting with better information and direction.

This project has met its goals of developing a short course for transferring technical information from the research community to the industrial community, to seek out the research needs of industry, and to continually upgrade course materials.